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ABSTRACT

This learning module, one in a series of 20 related training modules for apprentice stationary engineers, deals with pumps. Addressed in the individual instructional packages included in the module are the following topics: types, classifications, and applications of pumps; pump construction; procedures for calculating pump heat and pump flow; pump operation; and procedures for pump monitoring and troubleshooting. Each instructional package in the module contains some or all of the following: a lesson goal, performance indicators, a study guide, a vocabulary list, an introduction, instructional text, an assignment, a job sheet, a self-assessment activity, a post-assessment instrument, answers to the post-assessment instrument, and a list of recommended supplementary references. (MN)

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ED254707

APPRENTICESHIP

STATIONARY ENGINEERS

RELATED TRAINING MODULES

13.1 - 13.7 PUMPS

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STATEMENT OF DEVELOPMENT

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APPRENTICESHIP

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STATIONARY ENGINEER
SUPPLEMENTARY REFERENCE DIRECTORY

Note: All reference packets are numbered on the upper right-hand corner of the respective cover page.

Supplementary Packet #	Description	Related Training Module
12.1	Correspondence Course, Lecture 1, Sec. 2, Steam Generators, Types of Boilers I, S.A.I.T., Calgary, Alberta, Canada	12.1 Boilers, Fire Tube Type
12.2	Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Types of Boilers II, S.A.I.T., Calgary, Alberta, Canada	12.2 Boilers, Water Tube Type
12.3	Correspondence Course, Lecture 2, Sec. 2, Steam Generators, Boiler Construction & Erection, S.A.I.T., Calgary, Alberta, Canada	12.3 Boilers, Construction
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12.4	Corresondence Course, Lecture 4, Sec. 2, Steam Generators, Boiler Fitting I, S.A.I.T., Calgary, Alberta, Canada	12.4 Boilers, Fittings
12.5	Correspondence Course, Lecture 10, Sec. 2, Steam Generation, Boiler Operation, Maintenance, Inspection, S.A.I.T., Calgary, Alberta, Canada	12.5 Boilers, Operation
12.7	Correspondence Course, Lecture 3, Sec. 2, Steam Generation, Boiler Details, S.A.I.T., Calgary, Alberta, Canada	12.7 Boilers Heat Recovery Systems
12.8	Refer to reference packet 14.3/12.8	
		PUMPS
13.1 13.2 13.4 13.6 13.7	Correspondence Course, Lecture 9, Sec. 2, Steam Generator, Power Plant Pumps, S.A.I.T., Calgary, Alberta, Canada	13.1 Types & Classification 13.2 Applications 13.4 Calculating Heat & Flow 13.6 Monitoring & Troubleshooting 13.7 Maintenance
13.3 13.5	Correspondence Course, Lecture 6, Sec. 3, Steam Generators, Pumps, S.A.I.T., Calgary, Alberta, Canada	13.3 Construction 13.5 Operation

Supplementary Packet #	Description	Related Training Module
14.3 12.8	Correspondence Course, Lecture 6, Section 3, Steam Generators, Steam Generator Controls, S.A.I.T., Calgary, Alberta, Canada	14.3 Steam, Transport 12.8 Boilers, Instruments & Controls
14.4	Correspondence Course, Lecture 11, Section 2, Steam Generators, Piping II, S.A.I.T., Calgary, Alberta, Canada	14.4 Steam, Purification
15.1	Correspondence Course, Lecture 1, Sec. 4, Prime Movers & Auxiliaries, Steam Turbines, S.A.I.T., Calgary, Alberta, Canada	15.1 Steam Turbines, Types
15.2	Correspondence Course, Lecture 4, Sec. 3, Prime Movers, Steam Turbines I, S.A.I.T., Calgary, Alberta, Canada	15.2 Steam Turbines, Components
15.3	Correspondence Course, Lecture 2, Sec. 4, Prime Movers & Auxiliaries, Steam Turbine Auxiliaries, S.A.I.T., Calgary, Alberta, Canada	15.3 Steam Turbines, Auxiliaries
15.4	Correspondence Course, Lecture 6, Sec. 3, Prime Movers, Steam Turbine Operation & Maintenance, S.A.I.T., Calgary, Alberta, Canada	15.4 Steam Turbines, Operation & Maintenance
15.5	Correspondence Course, Lecture 8, Sec. 3, Prime Movers, Gas Turbines, S.A.I.T., Calgary, Alberta, Canada	15.5 Gas Turbines
16.2	Boilers Fired with Wood and Bark Residues, D.D. Junge, F.R.L., O.S.U. 1975	16.2 Combustion Types of Fuel
16.2	Correspondence Course, Lecture 5, Sec. 2, Steam Generators, Fuel Combustion, S.A.I.T., Calgary, Alberta, Canada	16.2 Combustion Types of Fuel
16.3	Correspondence Course, Lecture 5, Sec. 2, Plant Services, Fuel & Combustion, S.A.I.T., Calgary, Alberta, Canada	16.3 Combustion, Air & Fuel Gases
17.1	Correspondence Course, Lecture 12, Sec. 3, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.1 Feed water, Types & Operation
17.2	Correspondence Course, Lecture 12, Sec. 2, Steam Generation, Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.2 Feed water, Water Treatments

Supplementary Packet #	Description	Related Training Module
17.3	Correspondence Course, Lecture 7, Sec. 2, Steam Generators, Boiler Feed Water Treatment, S.A.I.T., Calgary, Alberta, Canada	17.3 Feed Water, Testing
18.1	Correspondence Course, Lecture 2, Sec. 5, Electricity, Direct Current Machines, S.A.I.T., Calgary, Alberta, Canada	18.1 Generators, Types & Construction
18.1 18.2	Correspondence Course, Lecture 4, Sec. 5, Electricity, Alternating Current Generators, S.A.I.T., Calgary, Alberta, Canada	18.1 Generators, Types & Construction 18.2 Generators, Operation
19.1	Corrspondence Course, Lecture 5, Sec. 4, Prime Movers & Auxiliaries, Air Compressor I, S.A.I.T., Calgary, Alberta, Canada	19.1 Air Compressors, Types
19.1 19.2	Correspondence Course, Lecture 6, Sec. 4, Prime Movers & Auxiliaries, Air Compressors II, S.A.I.T., Calgary, Alberta, Canada	19.1 Air Compressors, Types 19.2 Air Compressors, Operation & Maintenance
20.1	Basic Electronics, Power Transformers, EL-BE-51	20.1 Transformers
21.1	Correspondence Course, Lecture 7, Sec. 5, Electricity, Switchgear & Circuit, Protective Equipment, S.A.I.T., Calgary, Alberta, Canada	21.1 Circuit Protection
22.1	Correspondence Course, Lecture 10, Sec. 3, Prime Movers, Power Plant Erection & Installation, S.A.I.T., Calgary, Alberta, Canada	22.1 Installation Foundations

RECOMMENDATIONS FOR USING TRAINING MODULES

The following pages list modules and their corresponding numbers for this particular apprenticeship trade. As related training classroom hours vary for different reasons throughout the state, we recommend that the individual apprenticeship committees divide the total packets to fit their individual class schedules.

There are over 130 modules available. Apprentices can complete the whole set by the end of their indentured apprenticeships. Some apprentices may already have knowledge and skills that are covered in particular modules. In those cases, perhaps credit could be granted for those subjects, allowing apprentcies to advance to the remaining modules.

We suggest the the apprenticeship instructors assign the modules in numerical order to make this learning tool most effective.

SUPPLEMENTARY INFORMATION

ON CASSETTE TAPES

Tape 1: Fire Tube Boilers - Water Tube Boilers and Boiler Manholes and Safety Precautions

Tape 2: Boiler Fittings, Valves, Injectors, Pumps and Steam Traps

Tape 3: Combustion, Boiler Care and Heat Transfer and Feed Water Types

Tape 4: Boiler Safety and Steam Turbines

NOTE: The above cassette tapes are intended as additional reference material for the respective modules, as indicated, and not designated as a required assignment.

13.1

PUMPS -- TYPES AND CLASSIFICATIONS

Goal:

The apprentice will be able to describe types and classifications of centrifugal pumps.

Performance Indicators:

1. Classify pumps according to their method of operation.
   - Centrifugal
   - Rotary
   - Reciprocating
2. Describe types of pumps in each major class.

Study Guide

* Read the goal and performance indicators for this package.
* Read the vocabulary sheet to become acquainted with the trade terms that will be introduced in this package.
* Study the introduction and information sheets for technical information.
* Complete the job sheet.
* Complete the self-assessment sheet and check your answers with the answer sheet.
* Complete the post-assessment and ask the instructor to check your answers.

Vocabulary

* Axial flow pump
* Axially split casing
* Casing
* Centrifugal flow
* Centrifugal force
* Centrifugal pump
* Diaphragm pump
* Direct driven simplex pump
* Diffuse
* Double acting pump
* Double suction inlet pump
* Horizontal shaft pump
* Horizontally split casing
* Impeller
* Lobe pump
* Mixed flow pump
* Multi-stage pump
* Power driven pump
* Pump discharge
* Radially split casing
* Reciprocating pump
* Regenerative pump
* Screw pump
* Single acting pump
* Single suction inlet pump
* Single stage pump
* Sliding vane pump
* Spur gear pump
* Vertical shaft pump
* Vertically split casing
* Volute pump

Introduction

Pumps are used to move fluids from one place to another. There are many uses of pumps in industrial settings. Those uses include the movement of feedwater, fuel, cooling water, chemicals and condensate within the power plant.

Pumps are classified into major classes according to their method of operation. Each of the major classes is subdivided into types according to their design or application.

The pump is an important part of a power plant. The apprentice must understand the classes, types, functions and applications of pumps in order to operate power plant equipment.

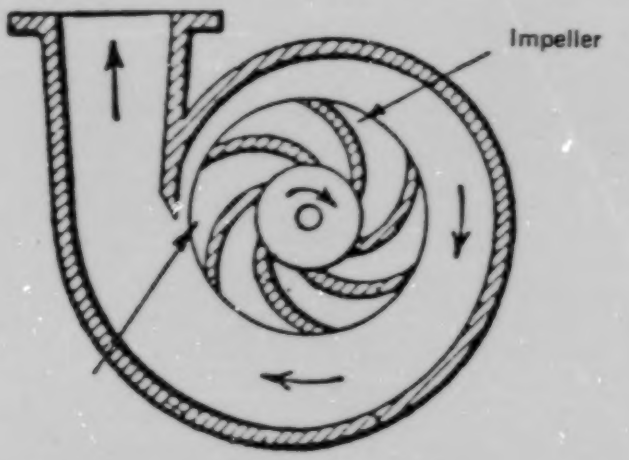
Information

In order to describe pumps, we must first classify them into groups with similar characteristics. All pumps can be classified into three groups according to their method of operation:

1. Centrifugal
2. Rotary
3. Reciprocating

Centrifugal Pumps

A centrifugal pump has an impeller that rotates inside a casing. The rotation of the impeller causes the liquid to move to the outside because of centrifugal force. As the liquid moves to the outside, it is forced through the pump discharge.



Types of Centrifugal Pumps

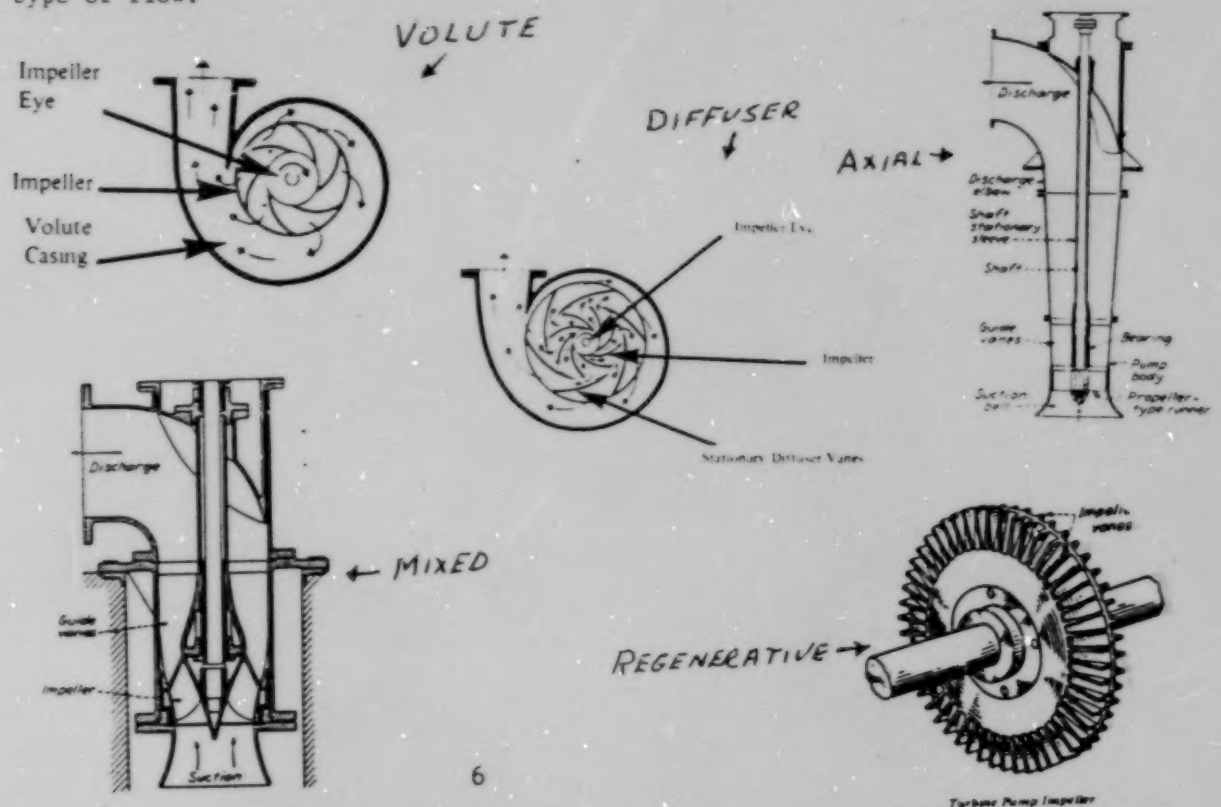
Centrifugal pumps may be further classified according to:

1. Type of flow -- centrifugal, axial, mixed flow or regenerative.
2. Number of stages -- single or multistage.
3. Type of casing -- horizontal or vertical split.
4. Position of shaft -- horizontal, vertical, submerged.
5. Suction -- single or double
6. Application -- general purpose, boiler feed pump, condensate pump, circulating pump.

Information

Types of Flow

A centrifugal flow is one that pulls the liquid into the eye of the impeller and discharges it from the outer rim of the impeller blades. The increased pressure forces the fluid into a discharge tube. A volute centrifugal pump consists of an impeller made up of vanes that rotates inside a volute casing. Volute means that the casing increases in cross-section as it nears the discharge area. A diffuser centrifugal pump is designed with vanes or diffusers between the impeller rim and the casing. The diffusers convert the high velocity liquid into pressure energy as it passes through the diffuser vanes. An axial flow uses impellers to provide lifting action on the liquid. The pump is arranged vertically and the impellers lift the liquid upward to the discharge tube. A mixed flow combines features of volute and diffuser centrifugal flow with axial flow. The pressure is developed by centrifugal force and axial lift of impeller vanes. A regenerative pump uses an impeller with a double row of vanes in its rim. Liquid enters the outer rim and is rotated almost a complete circle before being discharged from the outer rim. The regenerative pump is commonly called a turbine regenerative pump. The following diagrams show the features of each type of flow.



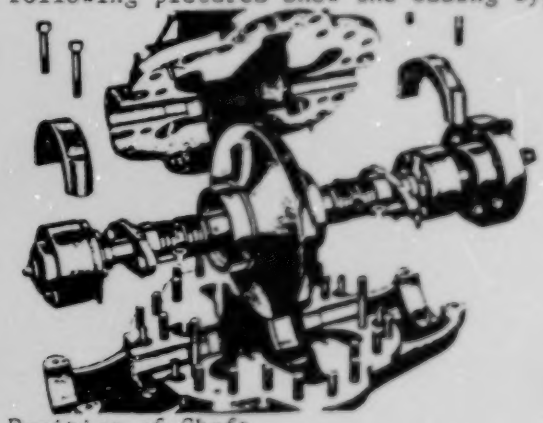
Information

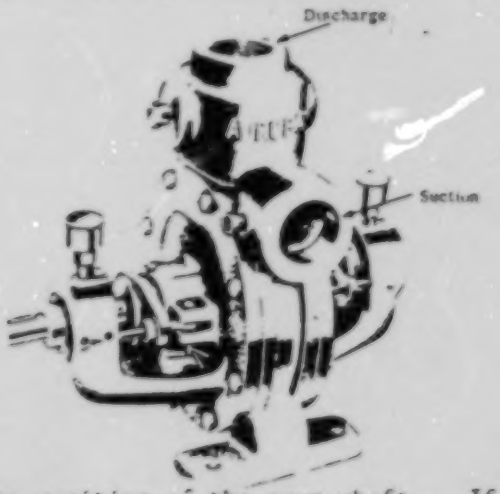
Number of Stages

A pump with a single impeller is called a single stage pump. When two or more impellers are operated in a series to give higher discharge pressures, it becomes a multi-stage pump.

Type of Casing

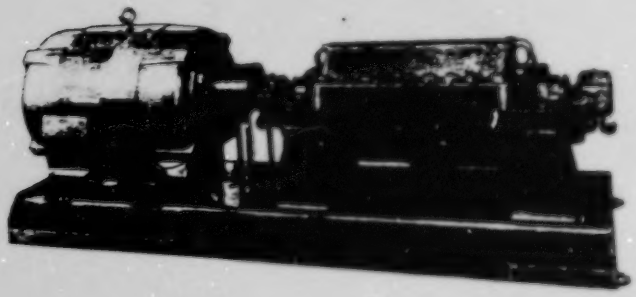
Pump casings are assembled in two sections so that the pump may be taken apart for inspection and repair. If the casing is divided along a horizontal plane it is a horizontally or axially split casing. When the casing divides along vertical lines it is called a vertically or radially split casing. The following pictures show the casing types.

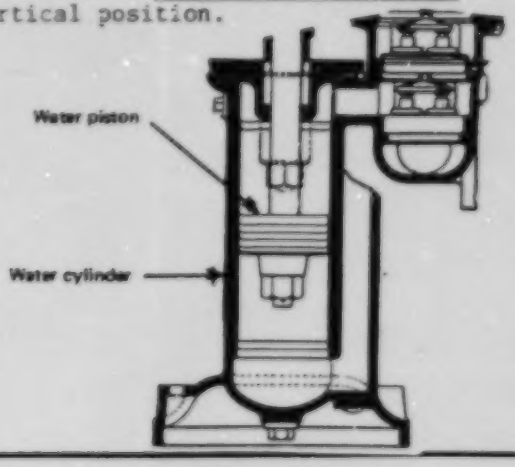




Position of Shaft

Pumps are sometimes classified according to the position of the pump shaft. If the shaft operates on a horizontal plane, it is called a horizontal shaft pump. On a vertical shaft pump the shaft lies in a vertical position.





Information

Suction

Water enters the impeller through the eye of the impeller. If water enters from only one side, it is a single suction inlet pump. One designed to allow water to enter the eye of the impeller from both sides is a double inlet pump.

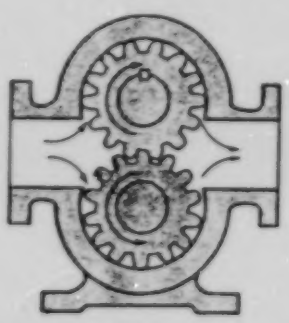
Rotary Pumps

Rotary pumps are positive displacement pumps. Positive displacement means that the pump will displace a given amount of fluid at any given time. Rotary pumps trap the liquid and push it toward the discharge. The major types of rotary pumps are:

1. Spur gear pumps
2. Lobe pumps
3. Sliding vane pumps
4. Screw pumps

Spur Gear Pumps

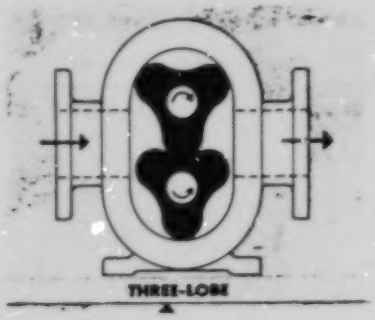
The spur gear pump consists of two gears that mesh together inside a housing. One gear is a driver and the other is an idler. The gears rotate and trap the liquid between the gear teeth. Liquids are carried in the spaces between the teeth toward the discharge. The liquids cannot return to the suction because the teeth mesh at the points of return. The following diagram shows how a gear pump operates to move liquid.



Information

Lobe Pump

The lobe pump operates much like the spur gear pump except that it uses rotors instead of gears for moving the liquid. The rotors have three lobes that trap the liquid and move it toward the discharge. A lobe pump is shown in the following diagram.



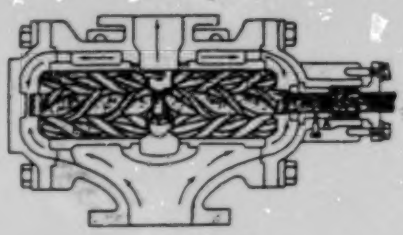
Sliding Vane Pump

The sliding vane pump uses an off-center rotor with sliding vanes to move liquid. The sliding vanes move out toward the housing by centrifugal force. Liquid is trapped between the vanes and moved toward the discharge. A sliding vane pump is shown in the diagram below.

Information

Screw Pump

A screw pump is made with one driver rotor sandwiched between two idler rotors. The rotors are made of threaded screw augers. The liquid is carried along the screw threads to the discharge. A screw pump is shown in the following diagram.

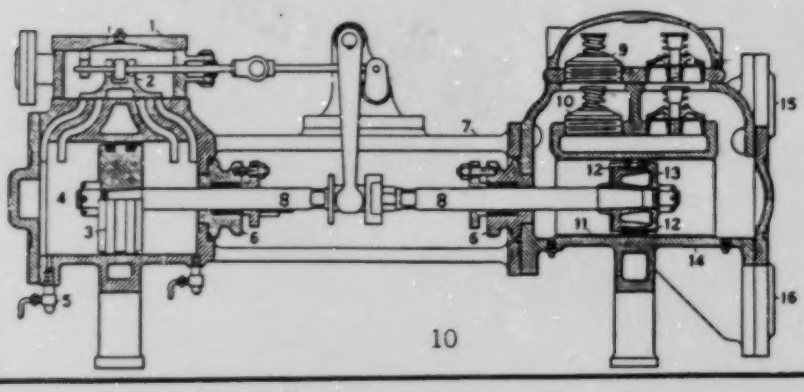


Reciprocating Pumps

A reciprocating pump uses the action of a piston, diaphragm or plunger to move fluid through the pump. Reciprocating pumps are positive displacement pumps. Several types of reciprocating pumps are used in steam generation.

Direct Driven Duplex Pump

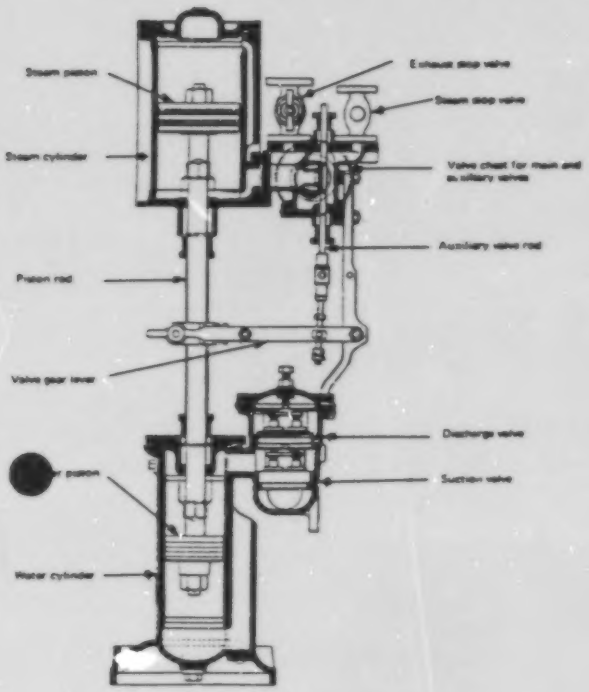
This pump uses drive pistons to drive the pumping pistons. The pumping pistons have overlapping action so that one is at maximum pressure while the other is at minimum pressure. This tends to smooth out the discharge of fluid. The diagram shows features of a horizontal duplex pump.



1. steam chest
2. slide valve
3. piston rings
4. steam cylinder
5. drain cock
6. stuffing box
7. cradle
8. piston rod
9. discharge valve
10. suction valve
11. liner
12. packing ring
13. liquid piston
14. liquid cylinder
15. discharge port
16. suction port

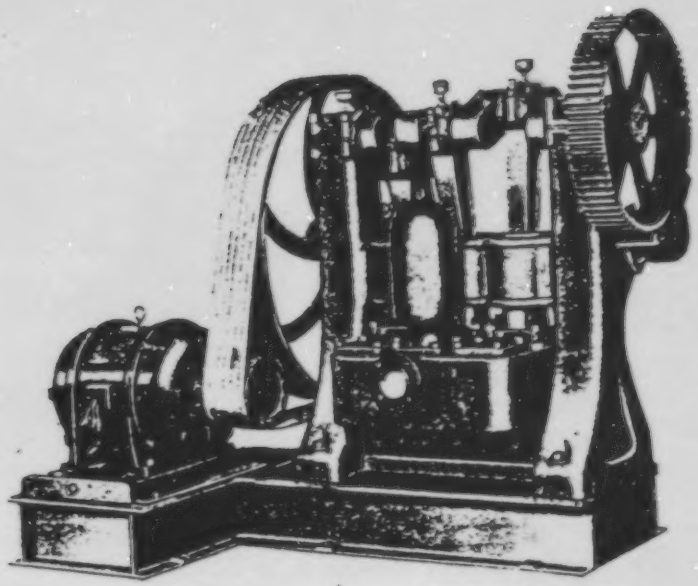
10

Information



Direct Driven Simplex-Pump

This pump has one driving piston and one double-acting pumping piston. The simplex pump may be of vertical or horizontal types.



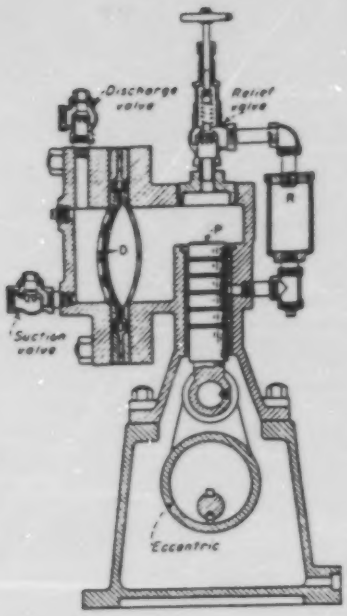
Power Driven Pumps

Power pumps are driven by some external power source through a crankshaft. A single acting pump discharges water from the cylinder only on the downstroke of the pumping piston. Double acting pumps discharge during each stroke. A power pump is shown in the photograph.

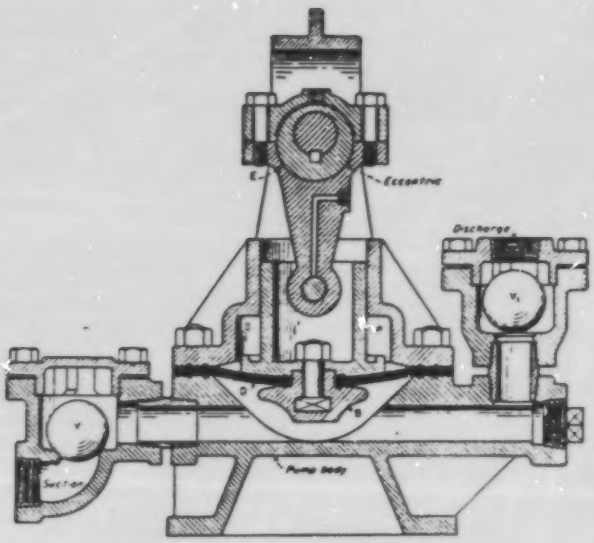
Diaphragm Pumps

Diaphragm pumps use a metal, plastic or rubber material for moving the liquid. The diaphragm is a flexible membrane that is operated mechanically or hydraulically. In this type of pump, the fluid does not come in contact with the reciprocating parts of the pump. In a mechanically actuated diaphragm pump an eccentric is used to flex the diaphragm and cause a pumping action. In a hydraulic actuated diaphragm, the piston pushes a fluid toward the diaphragm causing it to flex and give a pumping action. Diagrams of the two types of diaphragm pumps are shown on the next page.

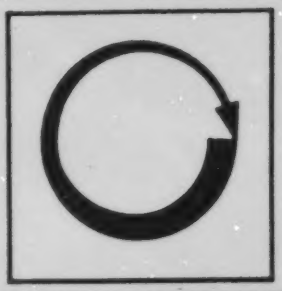
Information



Hydraulically Actuated Diaphragm Pump



Mechanically Actuated Diaphragm Pump



Assignment

* Complete the job sheet.
* Complete the self-assessment and check your answers with the answer sheet.
* Complete the post-assessment and have the instructor check your answers.

Job Sheet

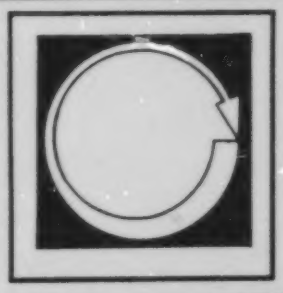
INVENTORY PUMPS AT WORK SITE

* Conduct an inventory of the pumps used at your work site. Classify them according to the major class and type shown in package.

PUMP #	LOCATION	CLASS Rotary, reciprocating, centrifugal	TYPE
1			
2			
3			
4			
5			
6			

* Keep the completed inventory sheet for use in other packages on pumps.

Self Assessment



Match the following pump types according to their class. (Reciprocating, rotary, centrifugal.)

____ 1. Direct driven simplex

____ 2. Spur gear

____ 3. Regenerative

____ 4. Axial flow

____ 5. Sliding vane

____ 6. Diaphragm

____ 7. Volute

____ 8. Diffuser

____ 9. Screw

____ 10. Lobe

A. Reciprocating

B. Rotary

C. Centrifugal

Self Assessment Answers

1. A
2. B
3. C
4. C
5. B
6. A
7. C
8. C
9. B
10. B

Post Assessment

Name 3 types of rotary pumps.

1.

2.

3.

Name 4 types of centrifugal pumps.

4.

5.

6.

7.

Name 3 types of reciprocating pumps.

8.

9.

10.

Instructor Post Assessment Answers

1.

2. Spur gear, lobe, sliding vane, screw

3.

4.

5. Volute, diffuser, axial flow, mixed flow, regenerative

6.

7.

8.

9. Direct driven duplex, direct driven simplex, power driven, diaphragm

10.

Supplementary References

* Correspondence Courses. Southern Institute of Technology. Calgary, Alberta, Canada.

INSTRUCTIONAL LEARNING SYSTEMS

13.2

PUMPS -- APPLICATIONS

Goal:

The apprentice will be able to describe applications and limitations of various types of pumps.

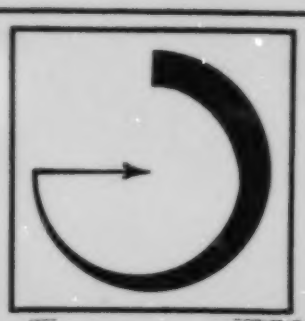
Performance Indicators:

1. Describe examples of pump applications in power plants.
2. Describe limitations of pumps.

Study Guide

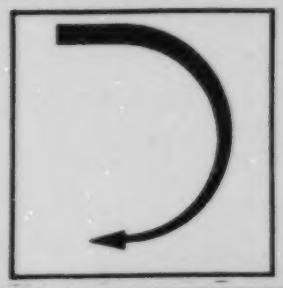
* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Ash handling pumps
* Boiler circulating pumps
* Boiler feedwater pumps
* Circulating pumps
* Chemical pumps
* Condensate pumps
* Fuel oil pumps
* Vacuum pumps

Introduction



Pumps are often described in relation to their intended applications. The apprentice must be able to relate the various pump types to the needs of a power plant.

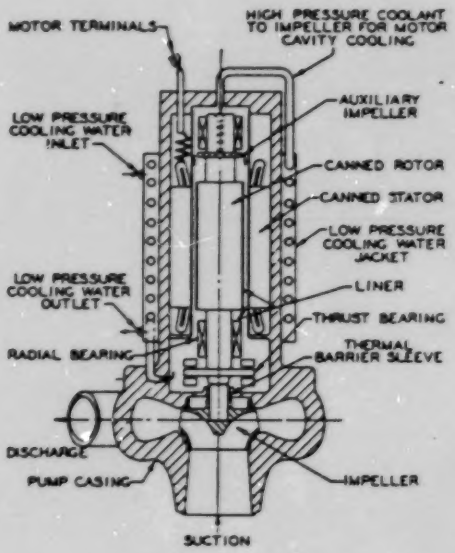
This package shows the major applications and the types of pumps used for each application. The special features or requirements for those applications are shown in a chart in the information sheet.

The apprentice should learn the applications of pumps described in the previous learning package -- "Pumps -- Types and Classifications". The job sheet will provide further understanding of pump types and applications.

Information

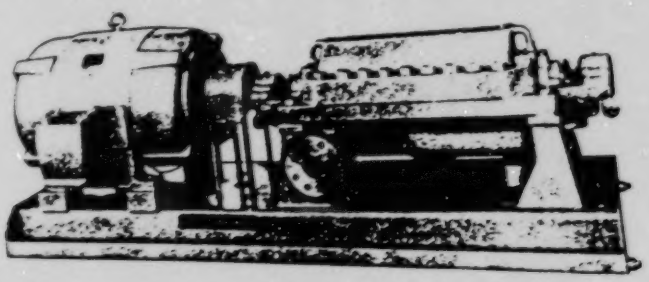
Boiler Circulating Pumps

Most boilers operate at high pressures and require forced circulation through the boiler tubes. Pumps are necessary to keep a flow through the boiler tubes.



Boiler Feedwater Pumps

Pumps are needed to provide the boiler with feedwater. The type of pump needed will depend on the capacity and pressure of the boiler that is being provided with feedwater.



Condensate Pumps

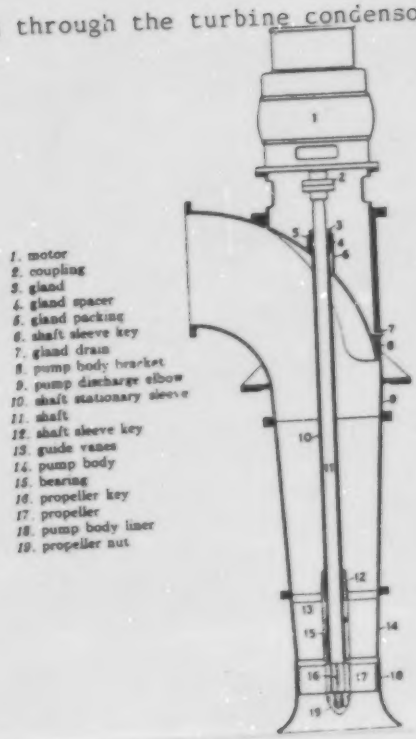
Condensate must be removed from the condensor hotwell and pumped to the boiler as feedwater. In some plants, the condensate pump also serves as a feedwater

Information

pump. High pressure steam plants use pumps to extract condensate from the steam condensors. These pumps are sometimes called extraction pumps.

Circulating Water Pumps

Large volumes of water must be moved through the turbine condensor to cool the steam into water form.



5 Propeller Type Circulating Water Pump

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Information

Fuel Oil Pumps

A pump is necessary for bringing the fuel oil from the storage tank to the boiler burners.

Chemical Feed Pumps

Boiler feedwater is treated with chemicals to neutralize some of the harmful effects caused by impurities in the feedwater. Pumps are required for handling these chemicals.

Vacuum Pumps

Vacuum pumps remove air and gases from the turbine condensor.

Ash Handling Pumps

These pumps are used to pump out ash that has been mixed with water to form a slurry.

information

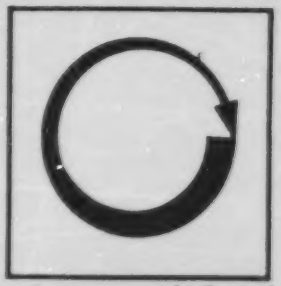
TYPES AND APPLICATIONS OF PUMPS

APPLICATION	TYPES OF PUMP	CHARACTERISTICS/LIMITATIONS
Boiler Circulating Pump	Conventional Drive	* Special shaft seals required when presures are high.
	Submerged motor - Wet type - Canned type	* Waterproof insulation for windings required. * Thermal barrier required to retard flow of heat from pumped water into motor of pump.
Boiler Feedwater Pumps	Reciprocating - Direct steam driven - Power driven	* Steam driven pumps limited to pressures less than 2750 kPa. * Power pumps cost more than steam pumps. * Power pumps are subject to increased wear when operating under high pressures and temperatures.
	Centrifugal - Volute - Diffuser - Regenerative	* Bartel type casing required when pressures exceed 10,000 kPa. * Regenerative pump used in small, low-pressure plants.

Information

APPLICATIONS	TYPES	CHARACTERISTICS/LIMITATIONS
Condensate Pumps	Centrifugal - Single stage	* Use large inlet to avoid flashing or cavitation. * Shaft glands must be water-sealed to avoid air leakage when on standby.
Circulating Water Pumps (Cooling water)	Centrifugal - Volute - Axial flow - Mixed flow	* Usually low head, large volume, low speed and single stage design. * 50% capacity pumps are often used.
Miscellaneous Pumps - Fuel oil pump	Rotary (positive displacement)	* Requires a relief or bypass valve to protect pump and discharge lines against excessive pressure.
- Chemical pumps	Reciprocating plunger type-motor driven	* Requires relief valve to avoid damage from over pressure.
- Vacuum pomps	Reciprocating piston type pump	* Positive displacement or jet type. Jet pump uses high pressure steam to operate.
- Ash handling pumps	Centrifugal (Single stage)	* Requires flat bladed impellers of wear resistant alloy.

Assignment



* Read pages 15 - 25 in supplementary reference.
* Complete job sheet.
* Complete self-assessment and check answers with answer sheet.
* Complete post-assessment and have the instructor check your answer.

Job Sheet

ANALYZE APPLICATIONS OF PUMPS AT JOB SITE

* Use the completed inventory from package (Pumps--Types and Classifications).

* Identify the application and characteristics/limitations for each pump on the inventory sheet. What is the pump used for? Add two more columns to the inventory sheet for applications and characteristics/limitations.

PUMP #	LOCATION	CLASS	TYPE	APPLICATION	CHARACTERISTICS/LIMITATIONS
Example:					
1.	Boiler Rm	Centrif.	Single Stage	Condensate Pump	Use large inlet to avoid cavitation.
2.					
3.					

* Ask your instructor to review the completed job sheet and suggest additions.

Self Assessment

List one type of pump that would be suitable for the following purposes.

1. Condensate pump

2. Fuel oil pump

3. Vacuum pump

4. Circulating water pump (cooling water)

5. Boiler circulating pump

6. Boiler feedwater pump

What is the purpose of the following?

7. Boiler feedwater pumps

8. Circulating water pumps

9. Fuel oil pump

10. Vacuum pump

Self Assessment Answers

1. Centrifugal
2. Rotary
3. Reciprocating
4. Centrifugal
5. Reciprocating -- convential drive or submerged water
6. Reciprocating or centrifugal
7. Provide boiler with feedwater
8. Move cooling water through turbine condensor
9. Brings fuel oil from storage tank to boiler furnace
10. Removes air and gases from the turbine condensor

Post Assessment

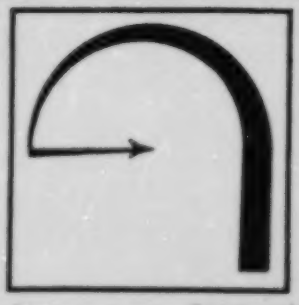
Match the following applications with the appropriate type of pump.

____	1. Boiler circulating pump	A.	Requires special shaft seals
____	2. Condensate pump	B.	Used in low pressure plants
____	3. Vacuum pump	C.	Reciprocating--steam driven
____	4. Boiler feedwater pump	D.	Rotary (positive displacement)
____	5. Circulating water pump	E.	Centrifugal--single stage
____	6. Fuel oil pump	F.	Reciprocating piston type
____	7. Chemical pump	G.	Submerged motor
____	8. Regenerative pump	H.	Reciprocating plunger type
____	9. Conventional drive pump	I.	Centrifugal--volute, mixed flow
____	10. Ash handling pump	J.	Centrifugal single stage with flat bladed impellers

Instructor Post Assessment Answers

1. G
2. E
3. F
4. C
5. I
6. D
7. H
8. B
9. A
10. J

Supplementary References



* Correspondence Course. Lecture 9. Section 2. First Class. Southern Institute of Technology. Calgary, Alberta, Canada.

13.3

PUMPS -- CONSTRUCTION

Goal:

The apprentice will be able to describe the construction of the major components of pumps.

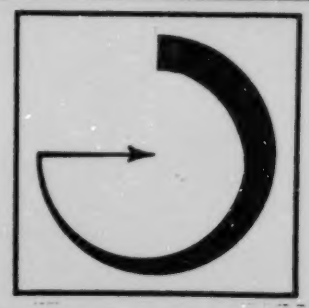
Performance Indicators:

1. Describe construction of reciprocating pumps.
2. Describe construction of rotary pumps.
3. Describe construction of centrifugal pumps.
4. Describe pump drives.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Axial thrust
* Balancing disc
* Balancing drum
* Balancing holes
* Ball (roller) bearing
* Double inlet impellers
* External gear pump
* Gland
* Impellers
* Induction motor
* Internal gear pump
* Lantern ring (seal cage)
* Lobe pump
* Mechanical seals
* "O" rings
* Packing
* Pump casing
* Pump shaft sealing
* Relief valve
* Rotating seal
* Screw pump
* Sealing ring
* Single inlet impellers
* Sleeve bearing
* Sliding vane pump
* Stationary seal
* Steam piston
* Stem guided valves
* Stuffing boxes
* Synchronous motor
* Thrust bearing
* Valve disc seats
* Valve stems
* Water piston
* Wear rings
* Wing-guided valves

Introduction

The efficiency of pumps is largely determined by the way its valves and seal function to prevent leakage of fluid back toward the suction. Also there is a problem of axial thrust that tends to move the impeller back toward the suction end of the pump.

Special packing and seals help to control the leakage. Axial thrust can be controlled by specialized components that counteract the forces that work on the impeller.

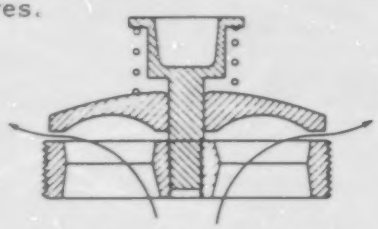
This package introduces the apprentice to some of the construction features of pumps.

Information

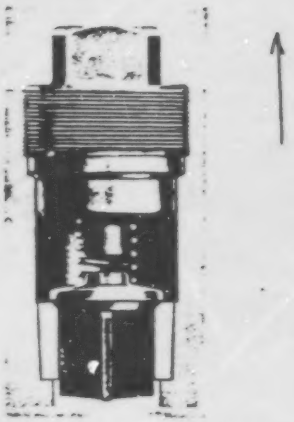
Components of Reciprocating Pumps

Pump Valves

Valve disc seats and stems are made of bronze or other alloy that will be wear resistant. Reciprocating pumps have many different designs for valves. The valves are stem-guided for low pressure systems and wing-guided for moderate and high pressures.



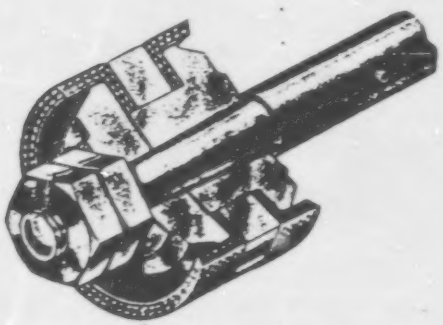
Stem-Guided Disc Valve

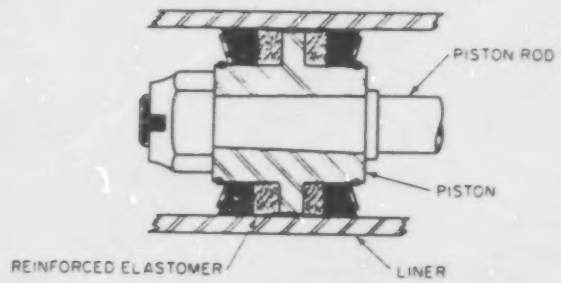


Wing-Guided Valve

Piston and Rod Packing

Reciprocating pumps have a steam piston with cast iron piston rings fitted into grooves. The rings prevent leakage between the piston and cylinder wall. Water pistons are sealed in the cylinder by square fibrous rings or packing. Packing is made with an asbestos core covered wtih canvas. Other means of packing include moulded cup and reinforced elastomer. The moulded cup is made of rubber reinforced with fabric. The reinforced elastomer packing consists of solid rubber rings and reinforced elastomer.





Information

Relief Valves

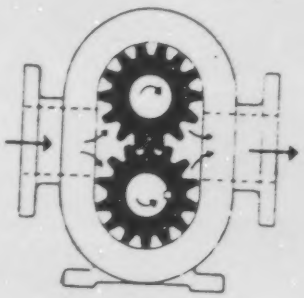
Power driven reciprocating pumps require a relief valve to prevent damage from overpressure. The relief valve is mounted on the pump discharge ahead of the first stop valve. Relief valves are not needed on steam driven reciprocating pumps.

Rotary Pumps

Rotary pumps are used for handling fuel, liquefied gases and hydraulic oils. These pumps use gears, lobes, vanes and screws to move liquids inside a casing. Rotary pumps are made in many designs. Some of the common designs are explained below.

External Gear Pump

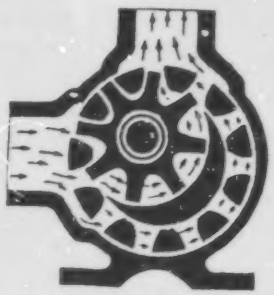
This pump has two gears that turn in opposite directions. The gears trap the liquid and move it toward the discharge. Gear teeth mesh to prevent the liquid from flowing back toward the inlet.



EXTERNAL-GEAR

Internal Gear Pump

The internal gear pump has one external cut gear that meshes with an internal cut gear on one side. A moon shaped partition prevents the liquid from passing back toward the inlet.

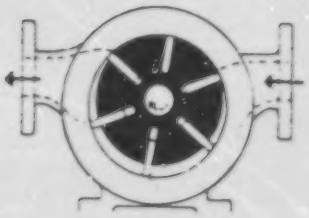


INTERNAL-GEAR

Information

Sliding Vane Pump

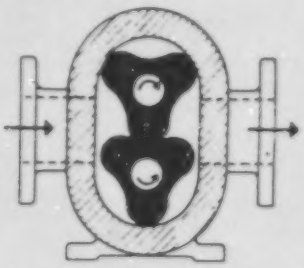
The sliding vane pump has a rotor that is mounted off-center in the casing. The rotor has vanes set in slots on the rotor. The vanes rotate close to the casing on one on one side and have clearance on the other. This forces liquids to move through the clearance toward the discharge.



SLIDING-VANE

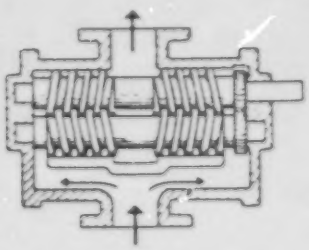
Lobe Pump

This pump has two rotors that are operated by external gears. The liquid is trapped in the pockets of the lobes and carried toward the discharge.



Screw Pump

Screw pumps are designed with two or three screw threads. Liquid is carried between the threads of the rotors and forced toward the discharge.



Information

Centrifugal Pumps

Impeller Types

Impellers are designed in many ways. The design depends on the speed, pump application and how the liquid is to be drawn into the impeller eye. Single inlet impellers pull liquid in from one side. The double inlet impeller pulls liquid in from both sides. The impeller may be constructed like a propeller or have vanes. Some impeller types are shown below.

Pump Casings

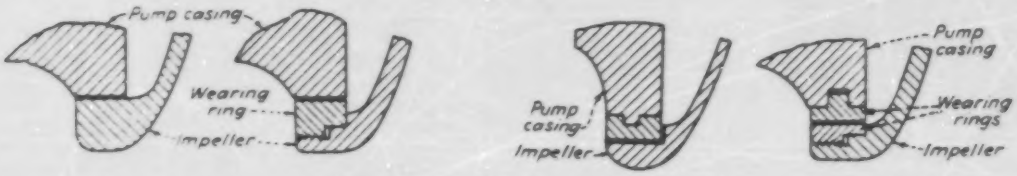
Centrifugal pump casings are split so that the pump can be opened for inspection. These pumps may be split horizontally, vertically or diagonally. Horizontally split casings are called axially split. Vertically split casings are termed radially split. Some centrifugal pumps are encased in a barrel casing to prevent leakage along the split. The barrel casing is an inner casing fitted into the outer casing.

Wearing Rings

The impeller must be sealed in the casing to prevent leakage. The seal is usually provided by a close tolerance joint between the casing and the rim of the impeller eye. As the pump operates, the joint wears and more leakage occurs. At that point, the clearance must be restored by building up the worn surfaces. The cost of restoring the clearance can be reduced by using wear rings. Wear rings are made of softer material than the casing or impeller. Wearing rings are made of bronze or cast iron so that the wear will be smooth.

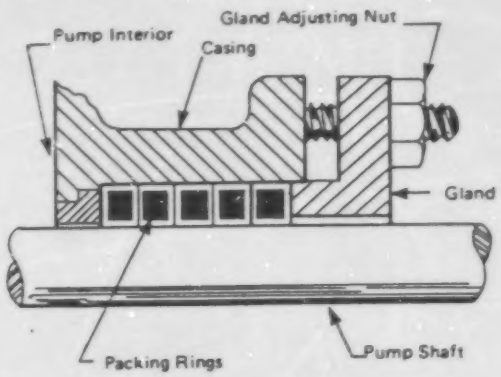
Information

The rings are available in continuous ring or half-ring types. They are fitted into ridges or grooves of the casing and secured with set screws.



Pump Shaft Sealing

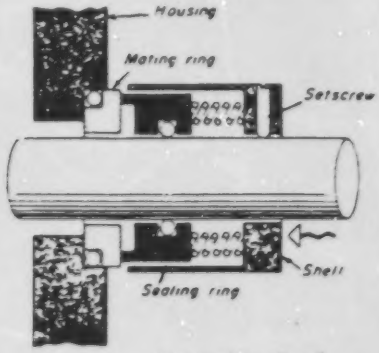
Leakage can occur where the pump shaft passes through the casing. To prevent such leakage, stuffing boxes or mechanical seals are used. A stuffing box is a recess around the shaft that holds a number of packing rings. Packing is held in place by a gland that compresses the rings.



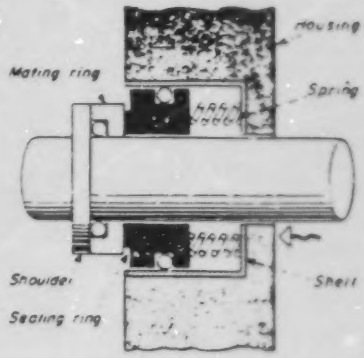
Packing rings are made of materials such as woven asbestos, nylon, flax or teflon. Metals such as lead, copper and aluminum are sometimes used as packing rings. The lantern ring (seal cage) is a metal ring with machined channels that distribute sealing liquid to the packing. The lantern ring is used in pumps that handle sand or other gritty materials.

Information

Mechanical seals are used in pumps that handle fuels, acids and other liquids where leakage is objectionable. Leakage is less than can be provided with stuffing boxes. The mechanical seal involves two flat rings with polished sealing surfaces. One ring (the sealing ring) is held in position by a spring. The other ring (mating ring) faces the sealing ring. There are two types of mechanical seals. The rotating seal has the sealing ring attached to the shaft so that it rotates with the shaft. The stationary seal rotates the mating ring while the sealing ring is attached to the pump housing. "O" rings are used to prevent leakage between the rings and the casing and shaft.



Rotating Seal



Stationary Seal

Pump Bearings

Centrifugal pumps use bearings to support the shaft and allow it to turn freely. Bearings are either sleeve or shell or ball or roller types. Small pumps have bronze bushings or sleeves that closely fit about the shaft. Large pumps use half-shell sleeve bearings that are made of cast-iron or steel and lined with babbitt. Many modern pumps use ball or roller bearings instead of sleeve bearings. Small shaft pumps use ball bearings while large shaft pumps use roller bearings.

Control of Axial Thrust

During the operation of a pump, forces tend to move the impeller out of position. This causes an axial thrust back toward the suction. Several ways have been developed for control of axial thrust. Thrust bearings on the shaft of low capacity pumps will control the problem. Balancing holes are used to control axial thrust on single-inlet pumps. Sometines axial thrust is controlled by facing impellers in a manner that the inlets are opposed to each

Information

other. A balancing drum can be installed on the shaft between the impeller and the balancing chamber. The drum tends to balance the thrust toward the discharge instead of the suction. Balancing discs can be used to control axial thrust when mounted on the shaft. The balancing disc is not widely used because it can have more problems than the balancing drum.

Pump Drives

Pumps are driven by many power sources. The most common power source is the electric motor. The squirrel cage induction motor is the most common. The synchronous motor is used for large capacity pumps. Steam turbines are often used to drive centrifugal and rotary pumps. Internal combustion engines can also be used to drive pumps.

Assignment

* Read pages 16-42 in supplementary reference and study diagrams.
* Complete the job sheet.
* Complete the self-assessment and check answers with answer sheet.
* Complete the post-assessment and have the instructor check your answers.

Job Sheet

DISASSEMBLE A CENTRIFUGAL PUMP

* Obtain a centrifugal pump (functional or non-functional).

* Remove half of the casing.

* Identify:

  - Type of impeller (single or double-inlet).
  - Type of flow (volute, diffuser, axial or mixed).
  - Type of casing (horizontal split, vertical split).
  - How wear rings are attached.
  - How pump shaft is sealed (stuffing bix, mechanical seal).
  - Location of gland.
  - Use of lantern ring.
  - Use of "O" rings.
  - Type of bearings.
  - How axial thrust is controlled (thrust bearing, balancing drum, balancing holes, balancing disc).
  - How pump is driven (type of motor, coupling).

* Ask instructor to explain those things that you do not understand.

Self Assessment

Match the following terms with the proper applications.

1. Stem guided valves	A. Used to drive large capacity pumps.
2. Wing guided valves	B. Prevents damage from overpressure.
3. Steam pistons	C. Type of impeller.
4. Water pistons	D. Used on high pressure systems.
5. Relief valve	E. Sealed in piston with cast iron piston rings.
6. Single-inlet	F. Type of packing.
7. Thrust bearings	G. Used on low pressure systems.
8. Stuffing boxes	H. Sealed in cylinders with packing.
9. Synchronous motors	I. Used to seal between shaft and housing.
10. Reinforced elastomer	J. Controls axial thrust.

Self Assessment Answers

1. G
2. D
3. E
4. H
5. B
6. C
7. J
8. I
9. A
10. F

Post Assessment

Match the following pump parts with their construction features.

1. Valve disc seats	A. Used to hold packing in place.
2. Induction motors	B. Casing opens along vertical line.
3. Balancing drum	C. Made with asbestos core covered with canvas.
4. Packing	D. Most common motor for pumps.
5. Synchronous motors	E. Used to drive large capacity pumps.
6. Reinforced elastomer	F. Made of bronze or alloy.
7. Moulded cup	G. Pulls liquid into one side only.
8. Radially split casings	H. Made with rubber reinforced with fabric.
9. Gland	I. Made of solid rubber rings and reinforcement.
10. Single-inlet impeller	J. Used to control axial thrust.

Instructor Post Assessment Answers

1. F
2. D
3. J
4. C
5. E
6. I
7. H
8. B
9. A
10. G

Supplementary References

* Correspondence Course. Lesson 6. Section 3. Third Class. Southern Institute of Technology. Calgary, Alberta, Canada.

INSTRUCTIONAL LEARNING SYSTEMS

13.4

PUMPS -- CALCULATING HEAD AND FLOW

Goal:

The apprentice will be able to calculate head and flow rates.

Performance Indicators:

1. Calculate net positive suction head.
2. Calculate change in pump power due to changes in size and speed of impeller.
3. Calculate change in head due to changes in size and speed of impeller.
4. Calculate change in quantity pumped due to changes in size and speed of impeller.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary

* Capacity
* Friction head
* kPa (Pascal)
* Net positive suction head
* Pressure head
* Pump efficiency
* Pump power
* Static discharge head
* Static head
* Static suction head
* Static suction lift
* Total head
* Velocity head

Introduction

Pumps must be selected according to the requirements of the job to be performed. In order to make wise selections of centrifugal pumps, someone must be able to calculate such things as head, power requirements of pumps, quantities of fluids that can be pumped and efficiency of pumps.

An apprentice should understand the basic principles of pumps and be able to make calculations needed for selection of pumps. The ability to make such calculations will insure a better job of matching pumps with the jobs they are to perform.

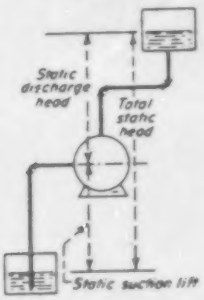
Information

Capacity

Capacity is the quantity of liquid handled by a pump in a given period of time. It is usually expressed as GPM (gallons per minute).

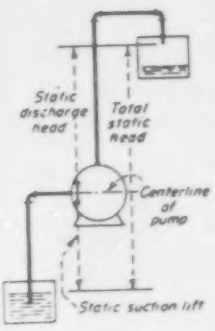
Static Head

Total static head is the total distance that a liquid moves in passing through a pump.



Static Discharge Head

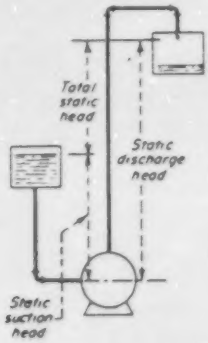
Static discharge head is the vertical distance from the center line of the pump to the surface of liquid in the discharge well.



Information

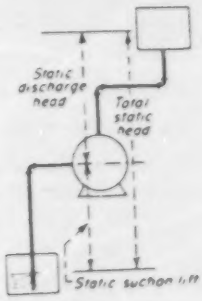
Static Suction Head

This is the vertical distance from the pump center line to the surface of the liquid in the source of supply. Static suction head exists when the supply is located above the center line of the pump.



Static Suction Lift

This condition exists when the source of supply is below the center line of the pump. It is the vertical distance from the surface of the liquid in the suction well to the center line of the pump.



Friction Head

This is the head needed to overcome friction of the liquid flow through the pipes and fittings.

Information

Velocity Head

The head through which a liquid would need to fall to acquire pumping velocity.

Pressure Head

The head caused by pressure of the liquid in the suction well or discharge well.

Total Head

Total head is the sum of static head plus velocity head plus friction head plus pressure head.

Net Positive Suction Head

This is the total head of liquid in feet at the suction nozzle, minus the vapor pressure of the liquid.

Calculating Head

In order to calculate head, one must first calculate pressure. Pressure is expressed in a unit called Pascal or in kPa (thousands of Pascals).

p = pressure (Pascals)
w = force of gravity (mass x density x 9.8)
h = height of free surface above point of measurement

For example, we wish to measure the pressure of water 5 meters below the surface. Water has a density of 1,000 kilograms per cubic meter. The formula would be:

p = wh
p = 1,000 x 1 x 9.8 x 5 = 49,000 Pa or 49 kPa

Other liquids will have other densities which will change the value of w in the formula. For example, gasoline has a relative density of .75. The same problem as above would be calculated as:

p = wh
p = 1,000 x .75 x 9.8 x 5 = 36,750 Pa or 36.75 kPa

Net positive suction head is used by pump manufacturers to express pump

Information

capacity. When selecting a pump, one must make certain that the net positive suction head requirements are met. The formula for net positive suction head is:

$$\text{Net positive suction head} = \frac{.1048\ (Pa - Pv)}{RD} + He - Hf$$

Pa = pressure of atmosphere or in the suction vessel
RD = relative density of liquid at pumping temperature
He = suction head in meters, either positive or negative depending on whether the pump is above or below the suction well
Pv = vapor pressure of liquid at pumping temperature in kPa from steam table
Hf = friction head in meters of suction piping

For example, a pump is lcoated 4.5 meters above the supply and is pumping 30oC water of RD of 1.0. The atmospheric pressure is 101.325 kPa and the friction head is .3 meters. Calculate the net positive suction head in this example:

Pa = 101.325 kPa
Pv = 4.246 kPa (from steam table)
RD = 1.0
He = -4.5 meters
Hf = .3 meters

$$NPSH = \frac{.10148\ (101.325 - 4.246)}{1.0} - 4.5 - 0.3$$

$$NPSH = 9.8516 - 4.8$$

$$NPSH = 5.85 \text{ meters}$$

Calculating Pump Performance (Centrifugal Pumps)

The quantity of water pumped will be affected by the size of the impeller and will vary according to the diameter of the impeller. Head will vary with the square of the impeller speed. The power to drive the pump will vary as the cube

Information

of the impeller speed or diameter. Head will also vary as the diameter of the impeller squared. Pump performance at different speeds and impeller sizes can be compared.

$$\text{Pump power (KW)} = \frac{\text{Kilograms of fluid delivered per minute} \times \text{Distance fluid is lifted in meters}}{6115.94}$$

For example, a pump is required to lift 400 kg of water for 8 meters:

$$KW = \frac{400 \times 8}{6115.94}$$

$$KW = .52$$

If KW = pump power
H = head (m)
D = impeller diameter (mm)
E = pump efficiency
n = pump speed (revolutions per minute)
Q = quantity pumped (liters per minute)

We can compare two pumps through equations. The effects of speed and impeller size on quantity pumped, head, power requirements and efficiency are considered in the following equations:

$$Q_2 = Q_1 \times \frac{n_2}{n_1} \times \frac{D_2}{D_1}$$

$$H_2 = H_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{D_2}{D_1}\right)^2$$

$$KW_2 = KW_1 \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{D_2}{D_1}\right)^3$$

$$E_1 = E_2$$

Information

Example:

A centrifugal pump delivers 20,000 liters per minute of water against a head of 40 meters when running at 2,000 revolutions per minute. The pump efficiency is 80 percent and requires 120 KW to drive the pump. The diameter of the impeller is 320 mm. If we reduce the impeller diameter to 300 mm and speed the pump to 2,100 revolutions per minute, what will be the performacne of the pump?

$$\text{Quantity pumped } Q_2 = Q_1 \times \frac{n_2}{n_1} \times \frac{D_2}{D_1}$$

$$Q_2 = 20{,}000 \times \frac{2100}{2000} \times \frac{300}{320}$$

$$Q_2 = 20{,}000 \times 1.05 \times .93$$

$$Q_2 = 19{,}520 \text{ liters per minute}$$

The change in impeller size and speed caused the pump to pump 480 liters less water per minute.

Let's take a look at the effect of those changes on head developed by the pump.

$$\text{Head } (H_2) = H_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{D_2}{D_1}\right)^2$$

$$H_2 = 40 \times \left(\frac{2100}{2000}\right)^2 \times \left(\frac{300}{320}\right)^2$$

$$H_2 = 40 \times 1.10 \times .86$$

$$H_2 = 37.84 \text{ meters}$$

The change in impeller size and speed would reduce the head 2.16 meters.

If we wish to compare the pump power requirements, the cube formula is used:

$$KW_2 = KW_1 \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{D_2}{D_1}\right)^3$$

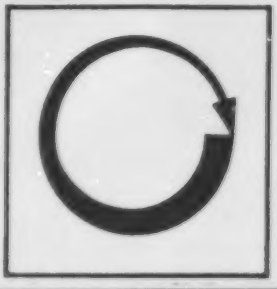
$$KW_2 = 120 \times \left(\frac{2100}{2000}\right)^3 \times \left(\frac{300}{320}\right)^3$$

$$KW_2 = 120 \times 1.33 \times .80$$

$$KW_2 = 127.20$$

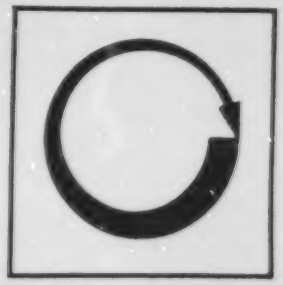
The required pump power would be increased by 7.2 KW as a result of changing the size and speed of the impeller.

Assignment



* Read pages 33-38 in supplementary reference.
* Complete the job sheet.
* Complete the self-assessment and check your answers with the answer sheet.
* Complete the post-assessment and ask the instructor to check your answers.

Job Sheet



IDENTIFY THE RATINGS OF A CENTRIFUGAL PUMP AT YOUR WORKSHOP.

* Find the rated speed of a centrifugal pump impeller. (n_1)
* Find the diameter of the impeller. (D_1)
* Find the rated flow of the pump. (Q_1)

Calculate the change in quantity that can be pumped by increasing the speed of the impeller by 100 revolutions per minute.

Self Assessment

Using the equations:

$$Q_2 = Q_1 \times \frac{n_2}{n_1} \times \frac{D_2}{D_1}$$

Calculate the change in quantity pumped by the following centrifugal pump when the impeller size is changed.

The pump now delivers 12,000 liters/minute against a 40m head when running at 1600 revolutions. The impeller diameter is 300 mm. If we change the impeller size to 320 mm and increase the speed to 1700 revolutions, how will the quantity of fluid pumped change?

Remember that Q_2 = Quantity pumped after change

Q_1 = Quantity pumped before change

n_2 = Pump speed after change

n_1 = Pump speed before change

D_2 = Impeller diameter after change

D_1 = Impeller diameter before change

Self Assessment Answers

$$Q_2 = Q_1 \times \frac{n_2}{n_1} \times \frac{D_2}{D_1^2}$$

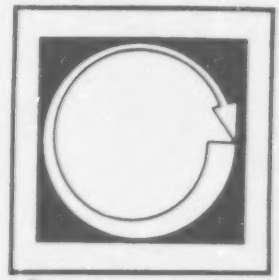
$$Q_2 = 12000 \times \frac{1700}{1600} \times \frac{320}{300}$$

$$Q_2 = 12000 \times 1.06 \times 1.06$$

$$Q_2 = 13{,}440 \text{ liters/per minute}$$

This is an increase of 1440 liters/per minute

Post Assessment



Using the equation:

$$H_2 = H_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{D_2}{D_1}\right)^2$$

Calculate the change in head developed by a pump as a result of changing speed and size of the impeller.

Problem:

A pump delivers 12,000 liters per minute against a 40 meter head when running at 1600 revolutions. The impeller diameter is 300 mm. If we change the impeller size to 320 mm and increase the speed to 1700 revolutions, what will be the change in head developed by the pump?

Remember: H_2 = Head after change

H_1 = Head before change

n_2 = Pump speed after change

n_1 = Pump speed before change

D_2 = Impeller diameter after change

D_1 = Impeller diameter before change

Instructor Post Assessment Answers

$$H_2 = H_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{D_2}{D_1}\right)^2$$

$$H_2 = 40 \times \left(\frac{1700}{1600}\right)^2 \times \left(\frac{320}{300}\right)^2$$

$$H_2 = 40 \times (1.06) \times (1.06)$$

$$H_2 = 40 \times 1.12 \times 1.12$$

$$H_2 = 50.17 \text{ meters}$$

The larger impeller size and increased speed results in an increase of 10.17 meters of head.

16

Supplementary References

* Correspondence Course. Lecture 9. First Class. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.

INSTRUCTIONAL LEARNING SYSTEMS

13.5

PUMPS -- OPERATION

Goal:

The apprentice will be able to describe steps in operation of pumps.

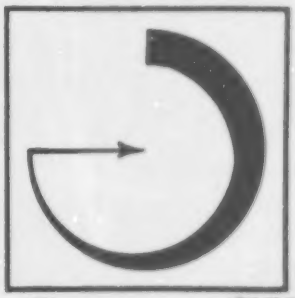
Performance Indicators:

1. Describe steps in priming of pumps.
2. Describe steps in starting a pump.
3. Describe steps in stopping a pump.
4. Describe cavitation.

Study Guide

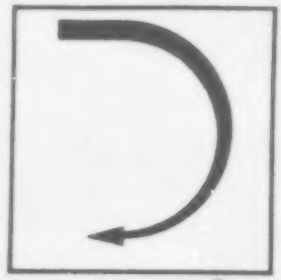
* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Air vent petcock
* Casing
* Cavitation
* Discharge valve
* Priming
* Suction line

Introduction



Pumps can be problems if the proper procedural steps are not followed in their priming, starting and stopping. The apprentice should learn the sequence of steps that avoid problems with pumps.

This package is designed to help the apprentice learn the proper operational steps so that priming, starting and stopping pumps will become a part of work habit.

Information

Priming a Pump

Reciprocating and rotary pumps are self-priming when in good condition and under normal lifts. Centrifugal pumps are not self-priming. These pumps must be primed with water before start-up. When the pump is located above the source follow the following priming procedures:

1. Fill suction line and casing with liquid through discharge valve bypass, auxillary line or be using a priming valve to draw air from the casing.
2. A foot valve on the suction line will allow liquids to enter the line but will prevent it from draining out.

If the pump is located below the supply, follow the following procedures:

1. Close discharge valve.
2. Open air vent petcocks.
3. Slowly open the suction valve.
4. Close air vent petcocks when liquid appears through them.
5. Open discharge valve before starting pump.

Starting Pumps

The following procedure should be followed when starting centrifugal pumps.

1. Check oil level in bearing housings.
2. Turn on cooling water for pump bearings, stuffing boxes and mechanical seals, if parts are water cooled.
3. Open suction valve and close discharge valve.
4. Close all drains in casing, suction and discharge piping.
5. Prime pump and open discharge valve.
6. Start pump and bring to speed.
7. Check leakage of stuffing boxes.
8. Adjust sealing liquid in stuffing boxes.
9. Check oil rings on sleeve bearings to see that they turn freely.
10. Check suction and discharge pressures.
11. Feel pump bearings for overheating.
12. If pump is being started for the first time:
    - Check that rotor turns freely.
    - Check alignment of pump and driver.
    - Check direction of rotation of driving motor.

Information

Stopping Pumps

When stopping centrifugal pumps, follow these procedures:

1. Close discharge valve slowly (large radial flow pumps).
2. Stop pump driver.
3. Shut off cooling water.
4. Close suction valve.

Cavitation

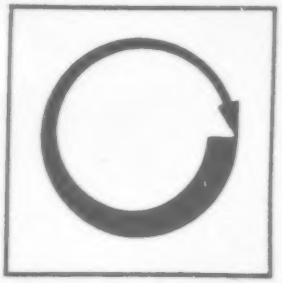
Cavitation is a condition caused by vaporization of liquids moving through a pump. It occurs when the pressure in the pump falls below the liquid vapor pressure. A vapor is formed as a result of the unequal pressure. Cavitation causes erosion of metal parts, vibration and pulsations as vapor pockets break down. Cavitation is caused by the following:

1. Suction velocity is too high.
2. Suction lift is too high.
3. Temperature of liquid is too high.
4. Suction line has too many sharp changes in its direction of flow.

Assignment

* Read pages 42-45 in supplementary reference.
* Complete job sheet.
* Complete self-assessment and check answers with answer sheet.
* Complete post-assessment and ask instructor to check your answers.

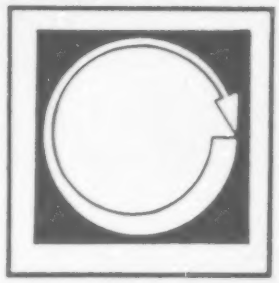
Job Sheet



PRIME A CENTRIFUGAL PUMP

* Locate a centrifugal pump at your work site and get permission to prime, start and stop it.
* Follow the procedures outlined in the information sheet.
* Prime, start and stop the pump in the proper sequence of operational steps.

Self Assessment



1. _____ pumps must be primed before starting.

2. A _____ valve on the suction line prevents liquid from draining out during priming.

3. The _____ valve must be closed before priming a centrifugal pump and opened before or immediately after the pump is started.

4. The air vent _____ must be open during priming.

5. _____ is a condition that occurs when liquid is converted to a vapor as it passes through the pump.

Self Assessment Answers

1. Centrifugal
2. Foot valve
3. Discharge valve
4. Petcocks
5. Cavitation

Post Assessment

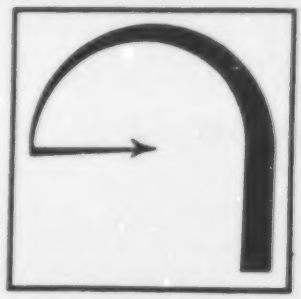
Explain the priming of a centrifugal pump when the pump is located below the source of supply. List the steps in the order that you would perform them.

Instructor Post Assessment Answers

The general steps for priming a centrifugal pump when the pump is below the source of supply are:

1. Close discharge valve.
2. Open air vent petcocks.
3. Open suction valve (slowly).
4. Close air vent petcocks when liquid comes through them.
5. Open discharge valve before starting.

Supplementary References



* Correspondence Course. Lecture 6. Third Class. Section 3.
Southern Alberta Institute of Technology. Calgary, Alberta, Canada.

13.6

PUMPS -- MONITORING AND TROUBLESHOOTING

Goal:

The apprentice will be able to describe monitoring and troubleshooting of pumps.

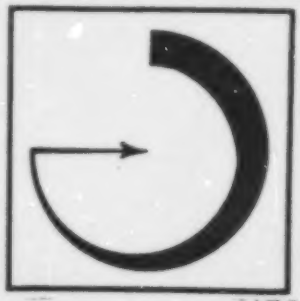
Performance Indicators:

1. Describe installation as it relates to troubleshooting.
2. Describe troubleshooting requirements of pumps.
3. Describe monitoring requirements of pumps.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Instal ation
* Monitoring
* Troubleshooting

Introduction

The installation of a pump is very important to monitoring and troubleshooting it while in operation. The manufacturer of the pump should be consulted about installation and their recommendations should be followed.

Once installed, the pump must be closely watched during its operation. This is called monitoring. When a problem occurs in the operation of the pump, the operator must be able to correct the problem. Problem identification and correction is called troubleshooting. Troubleshooting is a "quick fix" type of repair that involves simple operations such as replacing wear rings or seals.

This package is designed to introduce the apprentice to the basic concepts of installation, monitoring and troubleshooting. Preventive maintenance will be discussed in greater detail in a separate package.

Information

Installation

A pump should be installed in a location that is easily accessible for inspection and repair. Room should be allowed for removing the casing and rotor. Reciprocating pumps should allow room for removal of piston and rods. A pump should be located close to the supply to minimize the length of the suction line. Discharge lines should be short and with a minimum of fittings to reduce cavitation problems.

Where a pump is to work on suction lift, a foot valve should be installed along with a suction strainer. A gate valve should be placed in the discharge line close to the pump. Also a check valve should be installed between the gate valve and the pump.

Reciprocating pumps may require a surge chamber on the suction or discharge line. This chamber should be kept charged with air. A water level gauge is needed to check the amount of air in the chamber.

The pump manufacturer should be consulted about the installation of new pumps. Technical assistance should be requested from the manufacturer on installation procedures. Installation and alignment of pumps is a complex procedure and cannot be fully explained in this learning package. Additional information will be needed for proper installation.

Troubleshooting

The operator should always keep spare parts for pumps. The parts must be ordered in advance and catalogued for easy reference. The instruction manual should be close at hand and used as a guide for troubleshooting the specific pump that is giving trouble. Spare valves and packing should be available for troubleshooting reciprocating pumps. Bearings, shaft sleeves, wearing rings and packing will be needed for repairing centrifugal pumps. The instruction manual for each pump will provide guidelines for troubleshooting.

Monitoring Pumps

The best way to avoid pump outages is to establish a schedule of operational checks and a preventive maintenance program. Operating checks should be made hourly, monthly, quarterly, semi-annually and annually. These checks are made in much the same way as automobiles are maintained.

Information

In addition to the operations checks for maintenance purposes, the operator should listen to the pumps and make visual inspections on a continual basis. Unusual noises should alert the operator to problems. Loss of pressure on pressure gauges should be detected and action taken quickly.

Monitoring pumps requires an operator to use their senses of hearing, sight, smell and feeling of bearings that might be overheating. They must possess a sense of responsibility for the equipment and be alert to operating problems.

Assignment

* Read pages 27-32 in supplementary reference.
* Complete job sheet.
* Complete self-assessment and check answers with answer sheet.
* Complete post-assessment and ask instructor to check your answers.

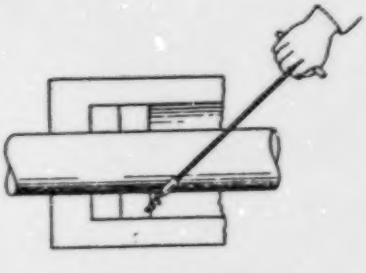
Job Sheet

REPLACE PUMP PACKING ON RECIPROCATING OR CENTRIFUGAL PUMP

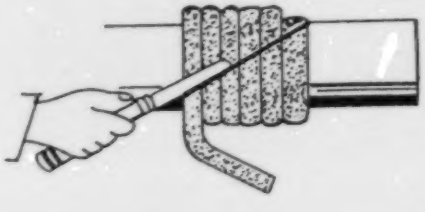
1. Shut down and drain pump.
2. Remove gland adjusting nuts and slide gland away from packing.
3. Remove all old packing with a packing puller tool.
4. Check condition of shaft or shaft sleeve and replace or resurface the shaft or replace shaft sleeve.
5. Determine correct size of packing to be used by:

   $$\text{Correct Size} = \frac{\text{Bore of stuffing box} - \text{Diameter of shaft or sleeve}}{2}$$

6. Wrap packing around shaft and cut the needed number of rings by diagonnally cutting packing coil with knife.
7. Place packing rings on shaft one at a time. Use oil or grease on the inside of each ring.
8. Tamp the rings into the stuffing box. Use metal ring to push each packing ring into place. Stagger the ring joints.
9. Replace gland and tighten gland nuts to squeeze packing. Slacken off on gland nuts to finger tight.
10. Prime and start pump.
11. Allow packing to leak for few minutes and then tighten gland nut to reduce leakage.



Removing Packing



Cutting Packing Rings

Self Assessment

1. When should a foot valve be installed on a pump line?

2. A _____ valve should be located between the gate valve and pump.

3. A water level gauge is needed to check the amount of _____ in a surge chamber of a reciprocating pump.

4. Which spare parts should be kept for reciprocating pump troubleshooting?

5. Which spare parts should be kept for centrifugal pump repair?

Self Assessment Answers

1. When pump works on suction lift.

2. Check valve.

3. Air.

4. Spare valves and packing.

5. Bearings, shaft sleeves, wearing rings and packing.

Post Assessment

1. What is the best way to avoid pump outages?

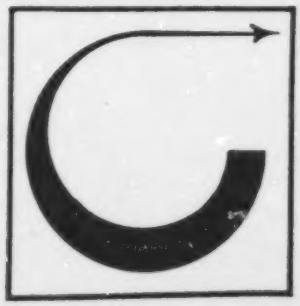
2. Where can troubleshooting information be obtained for specific types of pumps?

3. Why should a pump be located so that it is easily accessible?

4. Spare valves and packing should be kept for _____ pumps.

5. Bearings, shaft sleeves and wearing rings are good spare parts for _____ pumps.

Instructor Post Assessment Answers



1. Preventive maintenance operations check schedule.

2. Instruction manual for each pump. Obtained from pump manufacturer.

3. For inspection and repair.

4. Reciprocating.

5. Centrifugal.

Supplementary References

* Correspondence Course. Lecture 9. Section 2. First Class.
Southern Alberta Institute of Technology. Calgary, Alberta, Canada.

13.7

PUMPS -- MAINTENANCE

Goal:

The apprentice will be able to describe maintenance procedures for pumps.

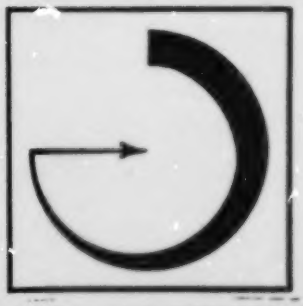
Performance Indicators:

1. Describe schedules for preventive maintenance of pumps.
2. Describe lubrication of pumps.
3. Describe maintenance of pump packing and seals.

Study Guide

* Read the goal and performance indicators to find what is to be learned from package.
* Read the vocabulary list to find new words that will be used in package.
* Read the introduction and information sheets.
* Complete the job sheet.
* Complete self-assessment.
* Complete post-assessment.

Vocabulary



* Gland
* Mating ring
* Mechanical seals
* "O" rings
* Preventive maintenance
* Pump packing
* Roller bearings
* Rotating mechanical seal
* Sealing ring
* Shaft sleeves
* Sleeve bearings
* Stationary mechanical seal
* Stuffing boxes
* Wearing rings

Introduction

Preventive maintenance is the key to success in pump operation. Most of the pump outages can be prevented by proper maintenance. A good maintenance schedule will assure that maintenance takes place before problems arise.

Lubrication of pumps will prevent wear of parts. Packing and seals must be replaced to avoid leakage and loss in pump efficiency. The apprentice should know how to care for and maintain pumps in a way that avoids costly outages. Otherwise, simple maintenance needs become major repair items.

Information

Maintenance Schedule

Preventive maintenance checks should be made to determine if the pump parts are working as they should work. The following items should be checked hourly during operation:

* Bearing temperatures (by hand)
* Suction pressure
* Discharge pressure
* Lubricating oil pressure and temperature
* Balancing disc leakoff
* Stuffing box leakoff
* Cooling water flow
* Cooling water inlet and outlet temperatures
* Amperage of driver motor
* Oil ring operation
* Recirculation or bypass flow

When any of the above items are not functioning normally, the problem should be corrected as quickly as possible.

Monthly checks should be made on the following:

* Bearing temperatures (by thermometer to get an accurate check)
* Correct hot bearing problems by adjusting the lubrication or alignment of pump and driver. Ball and roller bearings may run hot due to overlubrication. This problem can be corrected by removing lubricant. Sleeve bearings may not be receiving enough lubricant and run hot. Additional lubricant will correct the problem. Realignment of pump and driver may be needed to correct problems of hot bearings.

Quarterly checks should be made on:

* Dismantle, clean and change oil in sleeve bearings.
* Check all grease packed bearings for contamination. If contaminated , flush, clean and repack.
* Measure all bearings for wear and replace of needed.

Semi-annual checks should include:

* Check stuffing box leakage and renew packing.
* Check shaft sleeves for wear.
* Check for bent shafts, worn bearings and rotor balance.

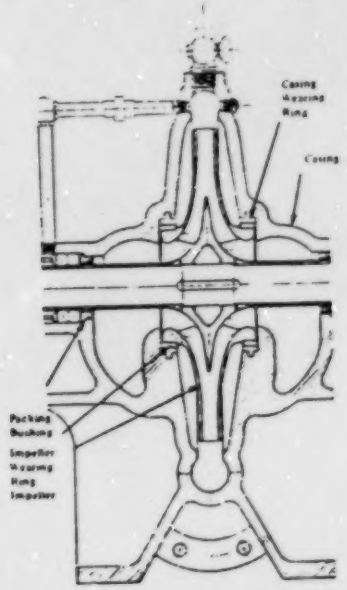
Information

Annual checks may involve a complete dismantling of the pump if it is giving poor performance. Such annual checks would include:

* Checking the casing for corrosion and wear.
* Checking rotor for corrosion and wear.
* Measuring wear ring clearance and replacing rings.
* Replacing worn shafts and sleeves.
* Flushing and cleaning coolant connections.
* Recalibration of pressure gauges.
* Checking bypass and recirculating valves for wear and replacing them when needed.
* Checking suction and discharge valve assemblies on reciprocating pumps.

Wearing Rings

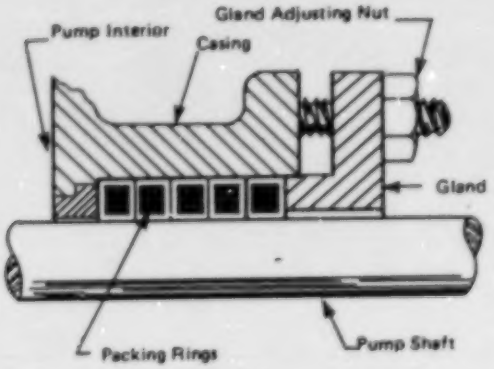
The wearing ring seals the impeller of a centrifugal pump into the casing. Rings may be mounted on either the impeller or casing or both. The rings are made of softer material than that of the surface it will be wearing against so that the impeller or casing does not wear. Wear rings are usually made of bronze or cast iron so that the wear will be smooth. The rings are set into the impeller rim by threading and held in place by set screws. Rings can be purchased as continuous or half rings. When fit on the casing, grooves hold the ring in place. The diagram below shows the location of wearing rings in a pump.



Information

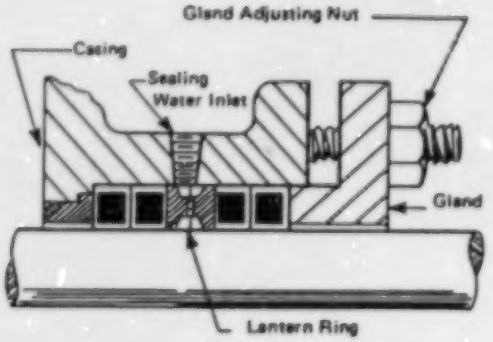
Stuffing Boxes

A seal is required between the casing and shaft of a pump. A stuffing box is a groove on the shaft that holds packing rings. The packing is held in place by an adjustable gland.



Stuffing Box with Packing

A lantern ring supplies sealing liquid to the packing to exclude air and provide lubrication. The lantern ring is needed by pumps that handle sand or other gritty materials. The sealing liquid keeps the sand from "eating up" the packing.

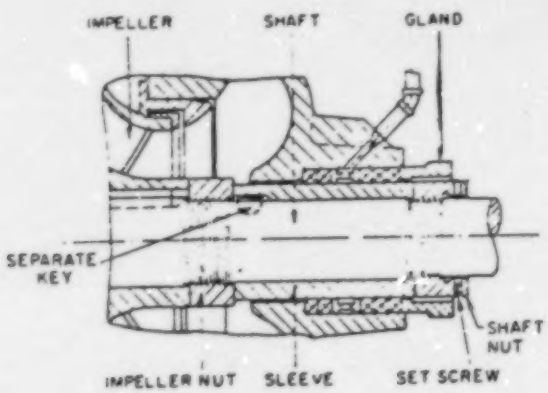


Stuffing Box with Lantern Ring

Information

Shaft Sleeves

A pump shaft is subject to wear and corrosion. Large pumps use shaft sleeves to take the wear instead of the shaft. When wear occurs, the sleeve is replaced. The sleeve is keyed on the shaft and held in place by the shaft nut.



Pump Packing

Pump packing is usually replaced every 3-6 months, depending on the operating conditions. Packing rings are cut from a coil and tamped into the stuffing box. The details of replacing pump packing are found in the Pump-monitoring and Troubleshooting package.

Mechanical Seals

On pumps that handle gasoline, acids and other touchy liquids, a mechanical seal is used in place of stuffing boxes. Mechanical seals reduce pump leakage and make it easier to work with such materials. A mechanical seal is two flat rings that rotate at right angles to the pump shaft. One ring is called a sealing ring and the other is a mating ring. The two rings are held in contact with each other by springs. On a stationary mechanical seal, the sealing ring is attached to the pump casing and the mating ring turns on the shaft. A rotating mechanical seal has the sealing ring attached to the shaft and the mating ring on the casing. A seal between the rings and casing are provided by "O" rings.

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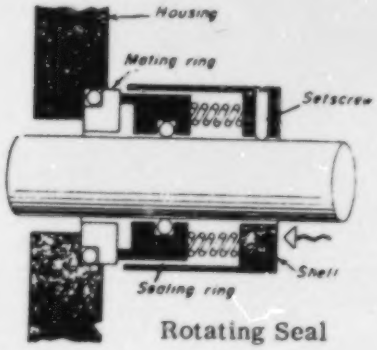
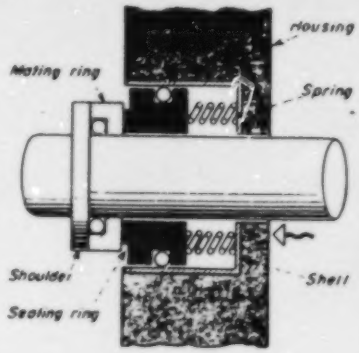
Information

In the maintenance of mechanical seals, the operator should make certain that the pump is never operated without being filled with liquid. All air should be vented from the seal housings before starting the pump. A flow of cooling liquid must be kept over the seals. Mechanical seals may leak due to scoring, grooving, distortion, misalignment or vibration. Manufacturers instructions should be carefully followed in maintenance of pumps with mechanical seals.



Rotating Seal



Stationary Seal

Bearings

Sleeve or shell bearings should be oil lubricated by drip lubricators. Ball or roller bearings may be lubricated by oil or grease. Ball or roller bearings should be lubricated with a high grade of lubricant and should never be overlubricated. They should be cleaned and lubricated on a regular, scheduled basis. Ball bearings are also called anti-friction bearings.

Assignment

* Read pages 27-32 in supplementary reference.
* Complete the job sheet.
* Complete the self-assessment and check answers with answer sheet.
* Complete the post-assessment and have instructor check your answers.

Job Sheet

COMPLETE AN HOURLY CHECK OF AN OPERATING PUMP

* Check the following:

  - Check bearing temperatures by hand
  - Check suction pressure
  - Check discharge pressure
  - Check lubricating oil pressure and temperature
  - Check leakoff on balancing disc
  - Check stuffing box leakoff
  - Check cooling water flow
  - Check cooling water inlet and outlet temperature
  - Check amperage of driver motor
  - Check recirculation or bypass control.

* List those problems that need to be corrected. Keep a written list of your readings.

* Ask instructor to validate your findings in regard to the maintenance problems of the pump.

* Discuss (with instructor) the best ways to correct problems.

Self Assessment

Indicate whether the following pump items should be part of an hourly, monthly, quarterly, semi-annually or annually operations check for preventive maintenance.

1. Cooling water flow
2. Stuffing box leakoff
3. Bearing temperatures by thermometer
4. Bearing temperatures by hand
5. Clean and change oil in sleeve bearings
6. Renew packing in stuffing boxes
7. Check grease packed bearings
8. Measure bearings for wear
9. Suction pressure
10. Amperage of driver motor

Self Assessment Answers

1. Hourly
2. Hourly
3. Monthly
4. Hourly
5. Quarterly
6. Semi-annually
7. Quarterly
8. Quarterly
9. Hourly
10. Hourly

Post Assessment

1. Packing rings are held in a stuffing box by the _____.

2. Sealing liquid is supplied to packing (on some pumps that pump sand or gritty materials) by a _____ ring.

3. Pump packing should be replaced every _____ months.

4. List two types of mechanical seals.

5. When are mechanical seals used?

6. A seal is provided between the rings of a mechanical seal and the pump casing by _____ rings.

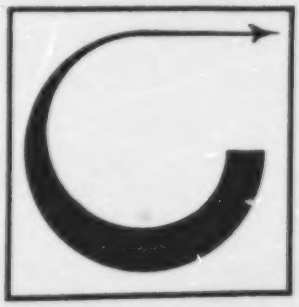
7. _____ bearings are also called anti-friction bearings.

8. Shaft _____ are used on large pumps to reduce wear on the shaft itself.

9. A complete dismantling of a pump is often a part of the _____ operations check.

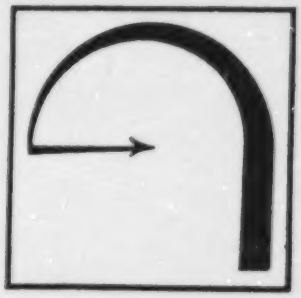
10. Wear rings are usually made of _____ or _____.

Instructor Post Assessment Answers



1. Gland
2. Lantern
3. 3 - 6 months
4. Rotating and stationary
5. When pumping gasoline or acid and excersive leakage is a problem.
6. "O" rings
7. Ball
8. Sleeves
9. Annual
10. Bronze or cast iron

Supplementary References



* Correspondence Course. Power Engineering. Lecture 9. Section 2. First Class. Southern Alberta Institute of Technology. Calgary, Alberta, Canada.